**GPS FOR GIS APPLICATIONS,** Carma Ingram – Monsen Engineering
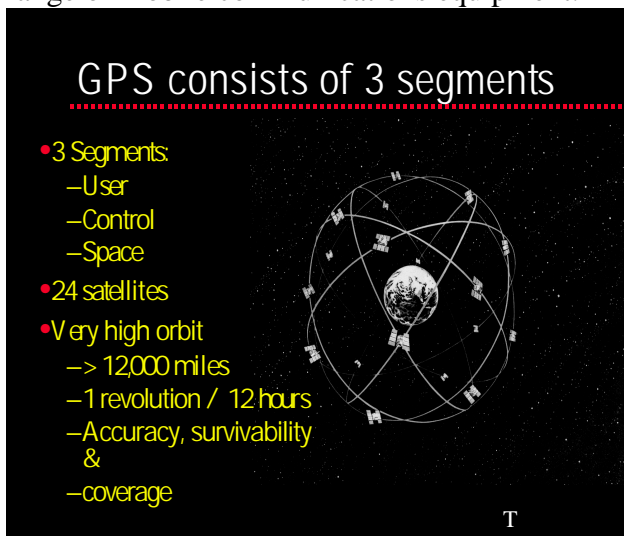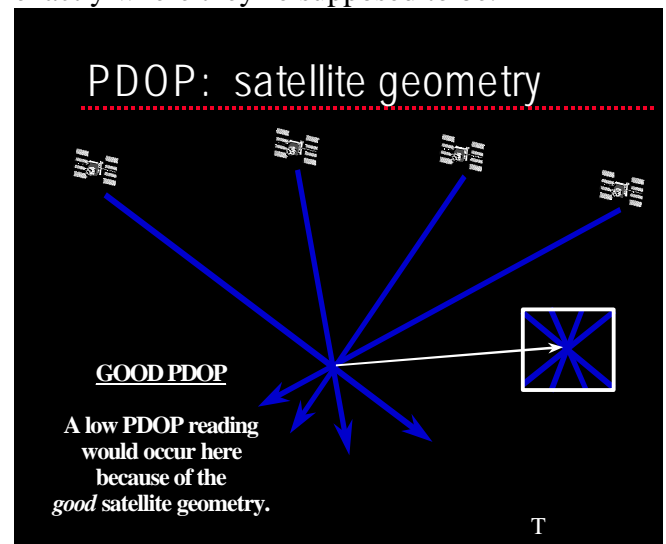
Use of the Global Position System – a way of accurately determining positions on the surface of the earth – has grown exponentially since it became feasible for commercial use in the early 1990s. Designed and developed originally for military use only, GPS is now used in mapping, navigation, surveying, agriculture, construction, vehicle tracking and recovery, archaeology, biology—the list goes on and on. In fact, GPS has become so widely used that it has now even found its way into a wide range of consumer products, from cell phones and automobiles to handheld "personal" receivers that have tumbled in cost from around $2,000 (the 1990 figure) to under $100. GPS chips are now being heavily used in computer networks, and popping up as well in such unlikely places as ATMs and entire range of mobile communications equipment.

Fortunately for people who wish to use GPS to fix locations, they need not even think about the satellites or the monitoring stations. Just like radio or broadcast televisions signals, GPS signals are available to anyone who has the proper equipment and knowledge. The twenty-four active satellites (there are currently three spares up there, too) have been deployed in six evenly distributed orbits, at speeds that have each satellite passing over a monitoring station once every twelve hours. That means there are always more than four visible in the sky everywhere on the planet. The satellites continuously transmit signals on two L-band frequencies, and the monitoring stations send correctional data to keep the satellites trim and exactly where they're supposed to be.
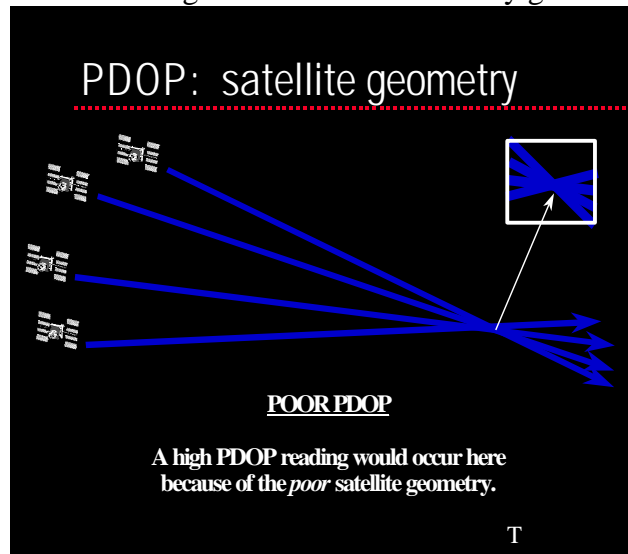


The Global Position System is a constellation of twenty-seven NAVSTAR satellites orbiting the earth at a height of 12,600 miles; five monitoring stations (in Hawaii, Ascension Island, Diego Garcia, Kwajalein, and exotic Colorado Springs); and individual receivers. By reading the radio signal broadcast from as few as three of these satellites simultaneously (a process known as trilateration), a receiver on earth can pinpoint its exact location on the ground. This location is expressed in latitude and longitude coordinates.
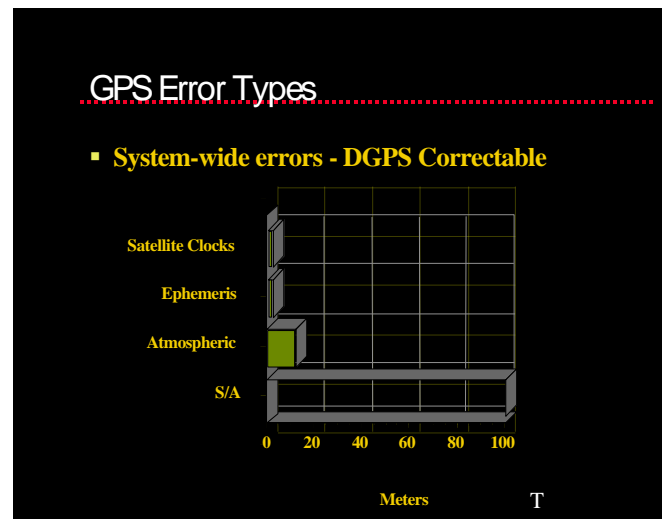


PDOP - The key to using the GPS system for accurate positioning relates to the relative position of the satellites you are using for your position. The ideal orientation of four or more satellites would be to have them equally spaced all around the receiver, including one above and one below. Because we're taking our position from only one side of the Earth, that's really not possible since that part of space is blocked by the planet itself. The best orientation is to have one satellite directly above and three evenly

spaced around the receiver and elevated to about 25 to 30 degrees (to help minimize atmospheric refraction). This would result in a very good DOP value (Dilution of Precision). A low numeric Dilution of Precision value represents a good satellite configuration, whereas a higher value represents a poor satellite configuration. The DOP at any given

## PDOP: satellite geometry

**POOR PDOP**

**A high PDOP reading would occur here because of the *poor* satellite geometry.**
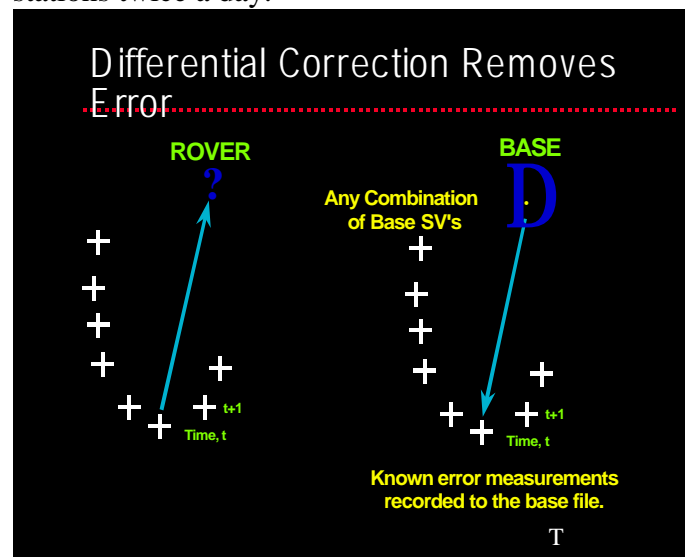
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moment will change with time as the satellites move along their orbits. The mapping grade GPS receivers monitor the DOP values and provide changeable mask settings that prevent the GPS operator from collecting poor positional data due to high DOP values.

**Selective Availability** was an intentional degradation of the GPS signal imposed by the U.S. Department of Defense (DoD). S/A was turned on in May 2000 because the DoD felt that we have enough radio jamming technology to be able to protect our country from unfriendly nations who would use the GPS system for navigational purposes of an attack nature. Keep in mind the DoD retains the power to turn it back on should the need arise. Without S/A the accuracy of GPS position is about 15 meters with great improvement also in the Z values.

## GPS Error Types

- **System-wide errors - DGPS Correctable**

Satellite Clocks

Ephemeris

Atmospheric

S/A

0   20   40   60   80   100

**Meters**          T

Other errors still inherent in the GPS signal relate to atmospherics error (distortion as the signal passes through our atmosphere), clock error (differences between atomic clock on the satellite and clocks in the receiver), and ephemeris errors (minor disturbances of satellite orbit caused by the sun and moon; gravitational pulls and the pressure of solar radiation). The five monitoring stations run by the DoD regularly transmit correctional data to the satellites as they pass overhead, each one of the stations twice a day.

## Differential Correction Removes Error

**ROVER**

**?**

**BASE**

**D**

**Any Combination of Base SV's**

t+1
**Time, t**

t+1
**Time, t**

**Known error measurements recorded to the base file.**

T

**Differential GPS** – The more sophisticated receivers can correct atmospheric and multipath errors, and can therefore be accurate—when the GPS data is differentially corrected—anywhere from 5-meter to sub-meter range. Differential correction requires two receivers. Place one receiver at a known location—an accurately

surveyed point.  This is the base station.  The other receiver, the rover, you carry around with you, logging latitude/longitude coordinates.  The base station receiver compares where the satellite the signals say it is with where it knows it is.  The difference is the amount of error.  The satellites are so far away that if the two receivers are close to each other—say within 300 miles—they will be subject to the same amount of error, having traveled through more or less the same corridor or atmosphere.

Generally, if the rover is within a hundred miles of a base station, the resulting positions will be accurate to within the specifications of the receiver.  The farther away you are, the less accurate the positions will be.  If the rover is 100 to 200 miles from the base, accuracy will be approximately two times worse than receiver specs; if the rover is 200 to 300 miles away, accuracy will be two-and-a-half to three times poorer than spec.  Recent advances in technology have made it possible to process over distances greater than 300 miles, but decreased accuracy is still a factor.  There are many, many public base stations providing their files for free over the Internet.  Some provide the files in Trimble .ssf format and others provide the files in a generic format called RINEX.

**Real-time versus postprocessing –** First, a word of caution:  it's not a good idea to rely on uncorrected GPS data, even with S/A turned off.  S/A's absence benefits mainly people using GPS for real-time navigation or autonomous positioning (Automatic Vehicle Location, for example), as well as recreational users:  hikers, campers, anglers.  Even though data collected without interference from S/A may be off by only 10 to 15 meters, the data can still be shifted from its actual position, and lines or polygons can appear spiky instead of straight.  Also, keep in mind that the DoD can scramble the GPS signal anytime it needs to.  If you want the accuracy your receiver is built to deliver, you have to differentially correct your data.

Real-time processing is generally less accurate than post processing because of the distance from the base station and latency in the

time the signal is received, as well as, the rate the signal is sent.
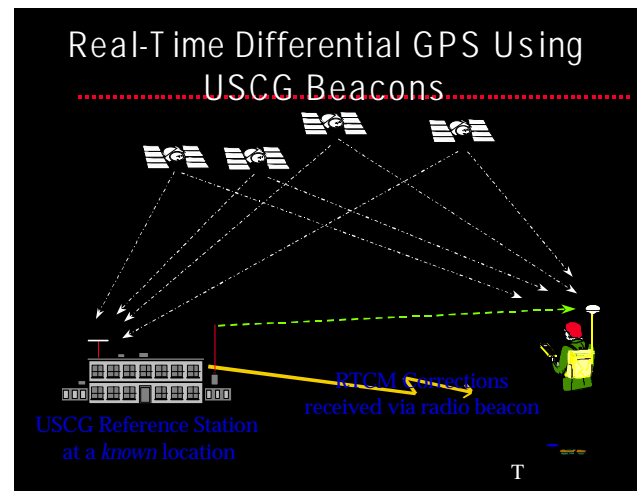


Several real-time differential correction radio signals are available.  The US Coast Guard has beacon transmitters  being placed strategically throughout the United States for eventual full coverage.  These signals operate at 200-300 MHz and are ground following from the radio transmitter.  You need a separate radio receiver to receive beacon signals.  Some receivers have the beacon radio receiver built in, others require a separate receiving radio.  Omnistar and Landstar provide real-time differential via a geostationary satellite for a fee of approximately $900 per year in the U.S.  Again, you need the radio receiving device to get that signal – some receivers have it built in, others require a separate radio receiving device.  WAAS signals are satellite differential provided by the FAA for accurate navigation of aircraft.  WAAS is still in the testing phase.  WAAS satellites use the same frequency as the GPS satellites; therefore, use one of your GPS channels.  They broadcast from an East coast and West coast located satellite and are fairly low on the horizon for use in the middle U.S.

For best accuracy post-process differential from a base station within 100 miles will yield the best result.

**Geographic Information systems (GIS)** – In a sense, GIS s simply a method of organizing and presenting virtually any kind of information about "stuff" in the world around us.  What "stuff?"  "Stuff" can be anything from fluvial systems (rivers), topography (shape of the

surface), land use (cities or fields), and "ordinary" road maps, to city sewer lines, telephone poles, fire hydrants and more. Basically, if it's out there it occupies space. If it occupies space then it has spatial characteristics such as *where* it's at, and individual characteristics like "big" or "small" or an individual serial number. This is all useful information to those who, in some form or another, plan, administer and manage such "stuff".

GPS fit hand-in-glove with the requirements of GIS. All of the information about "stuff" that's required for a computerized GIS can easily and accurately be acquired with GPS technology. The beauty of GPS for GIS applications is the simplicity and directness of data acquisition. For all intents and purposes, a GPS receiver can collect the necessary information and feed it directly into a computerized GIS with little effort expended in between.

The way GPS is used to provide GIS data can be categorized in two broad areas. The first is simply applying a controlling reference to some other source of data from which the GIS can collect the information that it needs. The other is to use the GPS to acquire the GIS information directly.
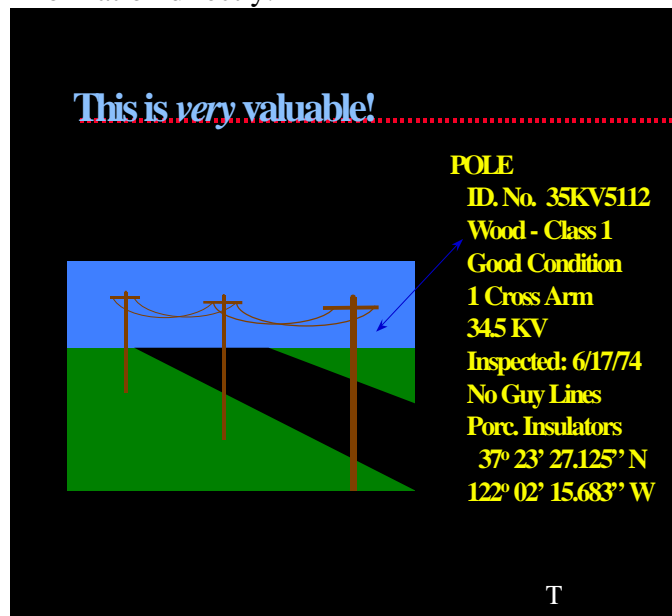


Using the GPS to acquire the GIS information directly requires the creation of a

data dictionary that will travel with you into the field to define information about the features you are collecting. To create a data dictionary, you will need to think of every feature you want to inventory as either a point, line, or area. For instance, trees, poles, and fire hydrants are points; fences, pipelines, and roads are lines; and land parcels or parking lots are areas. GPS positions are simply latitude/longitude coordinates, with no attribute—i.e., descriptive—data. GPS positions plotted as lines or areas are simply positions joined together, in the chronological order your collected them—a "connect-the-dots" puzzle. You need to think not only of features to be inventoried and how to define them, but also the questions about those features that need to be answered when you are in the field. In a GIS, this type of information is referred to as attribute data. For example, you might want to know a tree's species and height. In your data dictionary, the tree is the feature; the attributes, or questions, are species and height; and the answers to those questions are the values, which will be filled in by the user in the field.

Attribute types can be defined in a data dictionary as a menu choice, as text, or as a numeric, date, or time field. Using menu choices is often the best way to structure the attribute value because it insures that the spelling and structure of a word will always come into the GIS in the same way no matter who collects the feature in the field.

Mapping and high-resolution GPS systems have a wide range of application and they're much more accurate, principally because they are differential-capable. In addition, mapping grade receivers have some form of Feature/Attribute/Value recording capability for GIS applications. If you're concerned about the nearly instantaneous obsolescence that seems to plague consumers as computer technologies grow and change, keep this in mind: the foundation of a good GPS unit is the capability to both post process data and correct it in real time. Whatever else changes, your unit will remain viable and valuable for many years if it can perform these tasks.

No one really knows where GPS is going in the future. Ten years ago, no one had a clue that GPS would take off as it has. One thing for sure, it has become such a widely used technology in so many different areas, it is not going to go away. Advancements in the technology will include size, accuracy, power, battery technology and application specific software and more.



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